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An Operational Demonstration and Flight Test of the Microwave Landing System (MLS) at the Miami/Tamiami, Florida Airport

Vincent L. Bencivenga
Robert H. Pursel

July 1989

DOT/FAA/CT-TN89/37

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U.S. Department of Transportation
Federal Aviation Administration

Technical Center
Atlantic City International Airport, N.J. 08405

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16. Abstract
At the request of the Microwave Landing System (MLS) Program Office, the Federal Aviation Administration (FAA) Technical Center conducted an operational demonstration and flight test of the MLS at Miami/Tamiami, Florida Airport. The demonstration/flight test was conducted in conjunction with an MLS seminar jointly sponsored by U.S. Department of Transportation, FAA, and Transport Canada Aviation Group.

The Technical Center's MLS test bed, consisting of a 1.5° beamwidth elevation station and a 2° beamwidth azimuth station, was transported to, and temporarily installed at the Miami/Tamiami Airport on runway 9R, collocated with the commissioned instrument landing system (ILS). Additionally, an E-Systems preproduction model precision distance measuring equipment (DME/P) transponder was also installed adjacent to the runway 9R localizer equipment shelter.

On March 29, 1989, seven 1-hour demonstration and data collection flights were flown for over 60 aviation, industry, and U.S. and international Government attendees. By careful siting of the MLS on runway 9R, proportional MLS signal coverage was also obtained in the approach regions of runways 9L and 13. By utilizing an FAA Technical Center designed and fabricated MLS area navigation (RNAV) computer on board the demonstration aircraft, precision approaches were flown not only to runway 9R, but also to runways 9L and 13. This demonstrated the tremendous flexibility and operational capability of MLS. The MLS signal-in-space on runway 9R met Category II ILS tolerances. No degradation of the ILS performance due to the MLS collocation was detected during this demonstration.

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Microwave Landing System (MLS)
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Tamiami Airport Manager's Office, Mr. Clair Sherrick, Manager

Tamiami Sector Field Office, Mr. Carl Rubino, Manager

Miami Sector Field Office, Mr. George Priest, NAVAIDS Supervisor

Miami Sector Field Office personnel particularly Mr. Juan Rodriquez

Air Traffic personnel from Tamiami Tower and Miami Approach Control

Dade County Airport Department

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EXECUTIVE SUMMARY

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The Technical Center's MLS test bed, consisting of a 1.5° beamwidth elevation station and a 2° beamwidth azimuth station, was transported to, and temporarily installed at the Miami/Tamiami Airport on runway 9R. This system was collocated with the commissioned instrument landing system (ILS). Additionally, an E-Systems preproduction model precision distance measuring equipment (DME/P) transponder was also installed adjacent to the runway 9R localizer equipment shelter.

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INTRODUCTION

PURPOSE.

The purpose of this task was to demonstrate the capability of a microwave landing system (MLS) to operationally provide landing guidance for multiple runways from a single ground system at the Miami/Tamiami, Florida Airport. It was also intended to verify that an instrument landing system (ILS) and an MLS may be collocated without degrading the performance of either system.

BACKGROUND.

Miami/Tamiami Airport is surrounded by residential and small commercial buildings and farms. It is not a difficult site for an ILS to achieve satisfactory performance. The airport has two parallel runways (9L/27R and 9R/27L) and a crossing runway (13/31). The ILS is located serving runway 9R and is commissioned as a Category I facility. This airport is heavily utilized by general aviation aircraft.

An MLS seminar, jointly sponsored by the U.S. Department of Transportation (DOT), Federal Aviation Administration (FAA), and Transport Canada, Avionics Group, was taking place in Miami on March 28-30, 1989. Accordingly, the MLS Program Office requested the FAA Technical Center to temporarily install an MLS at the Miami/Tamiami airport for two purposes: (1) to demonstrate the MLS operational capabilities, and (2) to verify the ILS/MLS collocation procedures specified in draft form in ICAO Annex 10, volume 1, appendix J.

DISCUSSION

MLS EQUIPMENT AND SITING.

The back azimuth and elevation stations from the MLS test bed system installed for runway 31 service at the FAA Technical Center were selected for the Miami/Tamiami Airport installation. The MLS test bed is a modified Bendix FAR-171 MLS (model 1B-21.5-40) which meets the FAA MLS accuracy tolerances: FAA-STD-022B and FAA-STD-022C. The back azimuth antenna (figure 1) has a 2° beamwidth with +/- 40° proportional azimuth guidance, and the elevation antenna (figure 2) has a 1.5° beamwidth with coverage from $+0.9^{\circ}$ to 15° elevation. At the FAA Technical Center, front azimuth guidance is provided by a 1° beamwidth antenna with +/- 60° proportional guidance. This station was not required for the Miami/Tamiami installation.

Under a maintenance support contract with Bendix, the 2° back azimuth station was electronically reconfigured to a front azimuth station. New programmable read only memories (PROMS) were installed for the basic data words for the Miami/Tamiami site configuration. The scan rate was changed from 6.5 to 13 hertz (Hz). In lieu of concrete foundations, I-beam support frames (figure 3) were utilized for installation at Miami/Tamiami.

After the front azimuth and data word changes were made, the MLS was checked out at the Technical Center employing the C-band air sync provided with the system.

Air sync was required for Miami/Tamiami because land lines are not installed between the azimuth and elevation sites on runways 9R. Each antenna was removed from its pedestal and secured and packed for shipment. An instrumented test van with an MLS receiving antenna mounted on a telescoping mast (figure 4) was driven from the Technical Center to Miami/Tamiami for the system alignment prior to flight testing.

On March 30, the equipment was loaded on a flat bed truck for shipment to Miami/Tamiami (figure 5). It was delivered to the temporary MLS sites at 14:00 on March 23, unloaded, leveled, mechanically aligned (figures 6 and 7), and synchronized by 18:00 on the same day. Survey stakes, installed by FAA Technical Center personnel, were used for runway alignment. The elevation antenna was rotated 20^{o} about its vertical axis (towards the runway 9R centerline) in order to provide MLS elevation coverage for runway 13 as well as 9R and 9L. Power for the MLS sites was obtained from the ILS localizer and glide slope sites (arranged for by the Miami Airway Facility Sector (AFS)) and was connected to each station during this same 4-hour period. A layout of the siting geometry is shown in figure 8. A preproduction model precision distance measuring equipment (DME/P), manufactured by E-Systems, was utilized for ranging. This unit was installed at the ILS localizer transmitter site (figure 9).

Alignment of the MLS antennas were accomplished the next day using the instrumented test van. The MLS receiving antenna was placed over the surveyed points indicated in figure 10. The MLS receiver angle reading was used to set the boresight on the azimuth and elevation antennas.

ILS/MLS COLLOCATION.

The MLS was collocated with the commissioned Category I ILS serving runway 9R. Figure 11 shows the localizer/azimuth collocation, while figure 12 shows the glide slope/elevation collocation. Technical Center aircraft and personnel conducted an engineering flight test to baseline the performance of the ILS glide slope and localizer prior to the installation of the MLS. After MLS installation, the engineering flight test was repeated on the ILS. Test results indicated there was no effect on ILS performance due to the MLS installation. Additionally, a periodic flight check on the ILS was performed by an aircraft and personnel from the Aviation Standards National Field Office, Atlanta, Georgia, Flight Inspection Field Office. The ILS satisfied the periodic flight check as a Category I facility. Further details and data on the ILS/MLS collocation will be found in report DOT/FAA/CT-TN89/38 "ILS/MLS Collocation Tests at Miami/Tamiami Florida, Airport."

FLIGHT TEST AND DEMONSTRATION AIRCRAFT.

An FAA Convair 580, N-91 (figure 13), based at the FAA Technical Center was used as the flight test and demonstration aircraft. The aircraft is equipped with MLS antennas and project interface switching to allow either conventional navigation very high frequency omni-directional radio range (VOR) and ILS deviation signals or MLS deviation signals to be displayed on the cockpit instruments on the Captain's panel. In addition, project racks in the cabin area contained a Bendix/King ML-201A MLS receiver and a Bendix/King RNA-34AF digital flight inspection navigation receiver. Both of these receivers output both analog and digital data. Aircraft tracking was performed using a Warren Knight balloon theodolite and a JC Air FM radio telemetric theodolite (RTT) transmitter (figure

14). A prototype MLS area navigation (RNAV) computer, designed and fabricated by FAA Technical Center personnel, was also mounted on a project rack in the cabin. Using this computer, the MLS angle (θ, ϕ) data and the DME/P range (ρ) data are sent from the MLS angle receiver and the DME/P interrogator to the RNAV computer. There, the MLS triple (ρ, θ, ϕ) are converted to a cartesian triple (x, y, z) referenced to the desired runway datum. Computed position is then compared to a desired position based on prestored flightpaths, and lateral and vertical deviation signals are derived.

The MLS RNAV and data collection are contained in one dual purpose unit. The RNAV unit is currently configured as a level II RNAV computer capable of segmented approaches. Digital data are displayed on a control display unit (CDU). One CDU is mounted in the cockpit (figure 15) of the aircraft, while the other CDU is mounted on a project rack in the cabin of the aircraft. Figure 16 shows the display format and legend. Analog deviations generated by the RNAV computes are also displayed on conventional flight instruments in the cockpit.

The system hardware/software consists of the following:

1. 68020 32 Bit CPU

2. Floppy Disk Controller

3. One Floppy Disk Drive

4. Hard Disk Controller

5. One Hard Disk Drive

6. PDOS Operating System

7. C Language Software

8. Interface Boards for:

    a. Analog Aircraft Parameters
    b. Operator Terminal
    c. Time Code Generator
    d. ILS Receiver
    e. Cockpit Instruments
    f. Printer
    g. Kennedy Tape Recorder
    h. MLS Receiver
    i. DME Interrogator

A block diagram of the system is shown in figure 17.

DEMONSTRATION FLIGHTS.

On Wednesday, March 29, seven 1-hour demonstration flights were conducted for seminar participants (figure 18) at Miami/Tamiami Airport. Four approaches (figures 19 through 22) requiring the use of an MLS RNAV computer were designed for these flights. The first approach (figure 19) was flown during test and checkout flights but was eliminated from the demonstration routine because of time constraints.

Figure 20 depicts a straight-in approach to 9R with a glide slope transition from 4.5^{o} to 3.0^{o}. The initial segment (WPT 1 to WPT 2) is flown at a constant altitude computed from MLS data. At WPT 2, the profile commences a 4.5^{o} glide slope with respect to WPT 3. At WPT 3, the glide slope profile transitions to 3.0^{o} with respect to the runway datum. This approach was flown to a 100-foot decision height (DH) for demonstration purposes.

Figure 21 depicts an MLS RNAV approach to runway 13. The modified baseleg (WPT 1 to WPT 2) provides a 40^{o} intercept to the final approach course. The final approach course (WPT 2 to WPT 3) is a 3.5^{o} descent with respect to the runway datum. This approach was also flown to a 100-foot DH for demonstration purposes.

The last approach profile (figure 22) is an RNAV approach to runway 9L. This approach provides a 3.0^{o} glide slope with respect to runway datum. This approach was also flown to a DH of 100 feet.

Table 1 is a list of seminar participants who flew on the demonstration flights. Participants who held valid Air Transport Pilot (ATP) ratings were given the opportunity to fly these profiles. Additionally, during all demonstration flights, a team from the Ohio University Avionics Engineering Center (figure 23) provided aircraft tracking in x, y, and z using an Ohio University designed and fabricated tracking system. These data will be merged with airborne data to provide MLS RNAV system accuracies for report DOT/FAA/CT-TN89/40 "An Evaluation of the Accuracy of a Microwave Landing System Area Navigation System at Miami/Tamiami, Florida Airport."

CONCLUSIONS

1. The temporary installation of the microwave landing system (MLS) on runway 9R at the Miami/Tamiami Airport and the resultant flights satisfactorily demonstrated the operational capability of MLS at that site.

2. The test flights satisfactorily demonstrated the operational capability of an MLS, when combined with microwave landing system (RNAV) avionics, to provide landing guidance to multiple runways from a single ground system.

3. The test flights satisfactorily demonstrated that an MLS and an instrument landing system (ILS) may be collocated without degrading the performance of either system. Performance of the MLS during these tests met the requirements for ILS Category II signal-in-space.

TABLE 1. LIST OF PERSONNEL ON DEMONSTRATION FLIGHTS

Tour 1

Allman, Reynold - Barbados Government
Archer, Ezra - Barbados Government
Nicholls, Bert - Ministry of Int'l Transport (Barbados)
Leacock, Rudolph - Ministry of Int'l Transport (Barbados)
Arelland, Genaro - Direccion General of Civil Aeronautical (Chile)
Canobra, Marcelo - Lan-Chile
Valdivia, Patricio - Direccion General of Civil Aeronautical (Chile)
Ortiz, Manuel - Aviateca (Guatemala)

Herrera, Fausto - Fuerza Aerea Ecuatoriana (Ecuador)
Cadena, Marcelo - Direccion Civil Aviation (Ecuador)
Penafiel, Luis - Direccion Civil Aviation (Ecuador)
Gomez, Oscar - Commercial Jet Service
Guariguata, Andres - Viasa Airlines (Venezuela)
Mularski, Alex - Aerovias Venezocanas S.A. (Avensa) (Venezuela)
Diaz Ascanio, Edgar - Direccion Civil Aviation (Venezuela)
Martinez, Jesus - Cocesna (El Salvador)

Kvaal O. - Control Tower
WATTS, B. - Ground Tour Only

FAA Escorts

Dick Arnold - Airborne
Seymour Everett - Ground Tours
Carl Everberg - Airborne/Ground Tours

Tour 2

Gunter, Archibalde - Civil Aviation Dept. (Jamaica)
Roberts, Wilfred - Aeronautical Telecommunications Ltd. (Jamaica)
Seignoret, Gerard - Dept. of Civil Aviation (Trinidad & Tobago)
Ashby, Errol - Civil Aviation Div. (Trinidad & Tobago)
Cordero, Manuel - Aeroperu (Peru)
Montoya, Hugo - Aeroperu (Peru)
Garland, Ambassador Juan - Rep. of Peru to ICAO
Stehli, Carlos - ICAO (Peru)

Swann, Thomas - Civil Aviation Dept. (Turks & Caicos Islands)
Constantine, Ray - Dept. of Civil Aviation (British West Indies)
Martinez, Hector - Mexicana Airlines (Mexico)
Segovia, Francisco - Mexicana Airlines (Mexico)
Alfaro, Gerardo - TACA Int'l Airlines
Pierre, Jean L. - Civil Aviation Admin. (Haiti)
Aparicio, Jimmy - Dept. of Transport (Bolivia)
Carey, Philip - Grand Bahama Airport Co.

TABLE 1. LIST OF PERSONNEL ON DEMONSTRATION FLIGHTS (CONTINUED)

FAA Escort

Carmen Carrion

Tour 3

McClendon, Mike - American Airlines
Travis, Tom - American Airlines
Verbaarschot, Piet - Fokker Aircraft (The Netherlands)
Williamson, Keith - Boeing Canada DeHavilland Div.
Purifoy, Franklin - ICAO/PCA Saudi Arabia
Shafer, Robert - ICAO/OACI (Mexico)
Ward, Susan - FAA
Bosco, Thomas - Port Authority of NY & NJ

Bullock, Bob - Port of Seattle
Diblasi, Frank - FAA
Fajardo, Gonzalo - Avianca (Columbia)
Zeltser, Melvin - Mitre
Fromme, W. - ICAO
Jamison, Stuart - U.S. Mission to ICAO (Canada)
Adams, Mark - FAA
Evans, W. D. - Dept. of Industry, Science, and Technology (Canada)

FAA Escort

Lillian Cruz

Tour 4

McGrew, Carl - Westinghouse Electric Corp.
Hanson, Bob - Bendix King
Romrell, Glen - E-Systems
Burkley, James - Raytheon
Sinclair, Don - Pelorus Nav. Sys. Inc. (Canada)
Hastie, Jim - Canadian Marconi Company
Miller, Stan - Nec Corporation
Koch, Conrad - Bell Aerospace Textron
Underwood, David - Micronav (Canada)

FAA Escort

Carmen Carrion

FIGURE 1. BACK AZIMUTH STATION ANTENNA

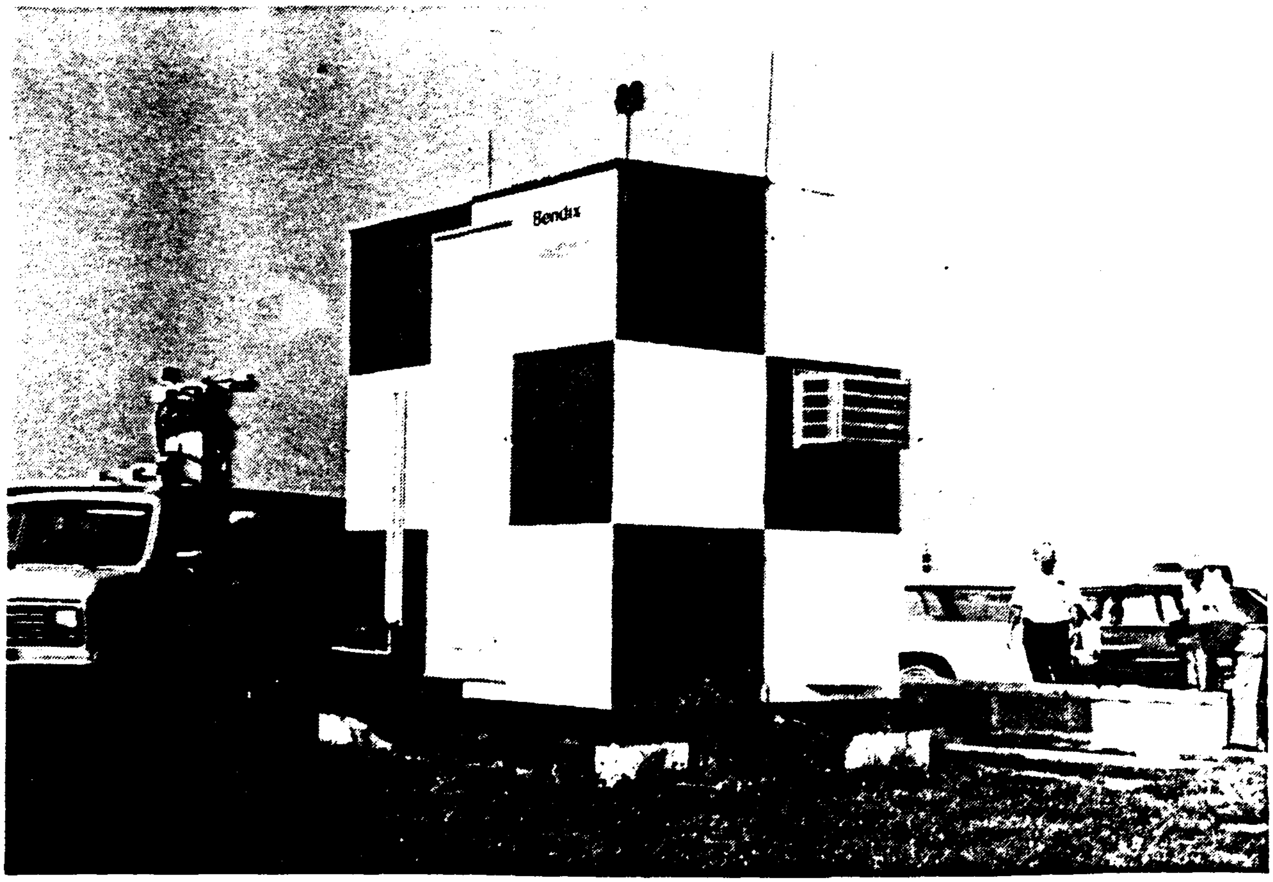


FIGURE 2. ELEVATION STATION ANTENNA

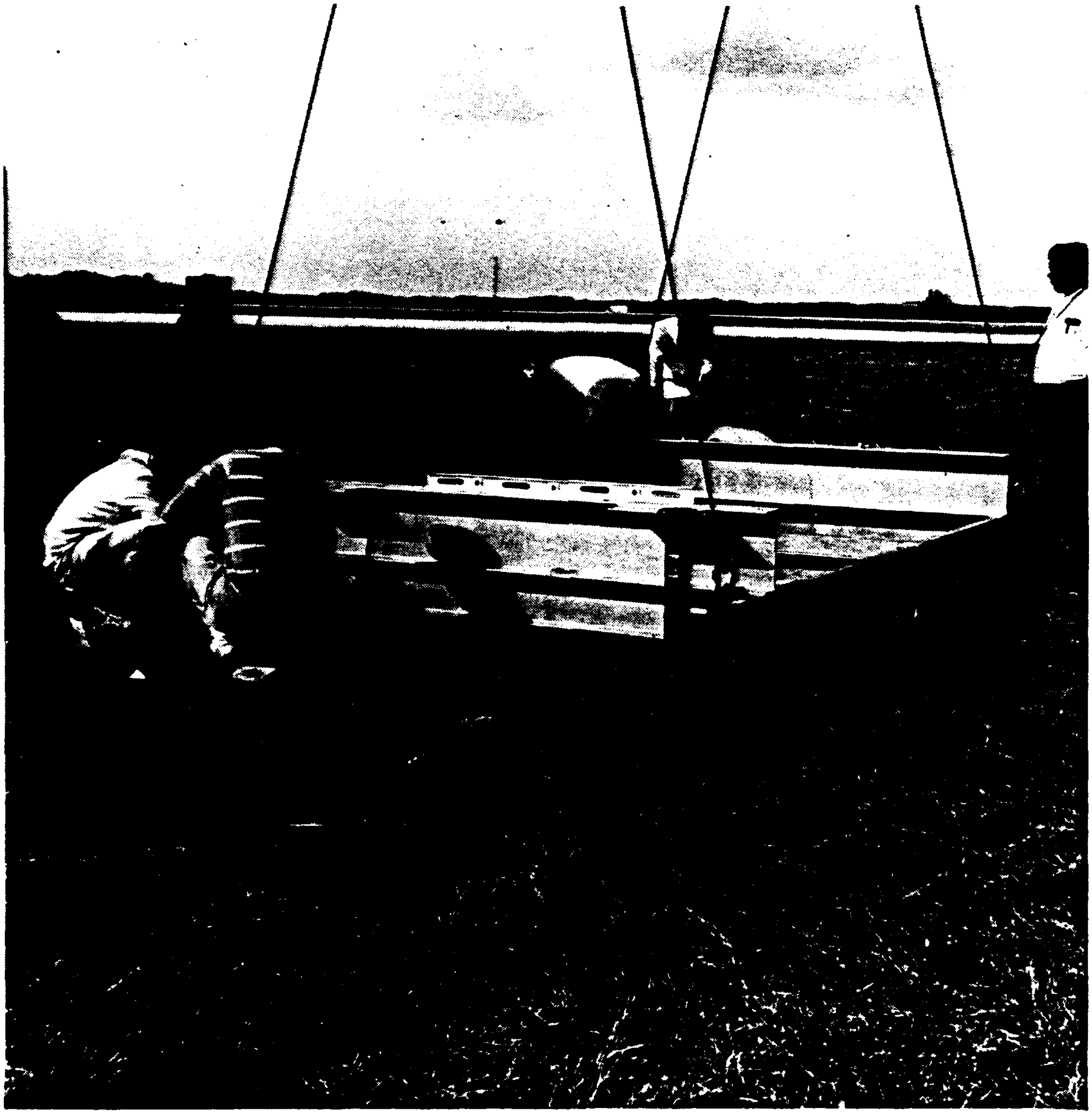


FIGURE 3. I-BEAM SUPPORT FRAMES

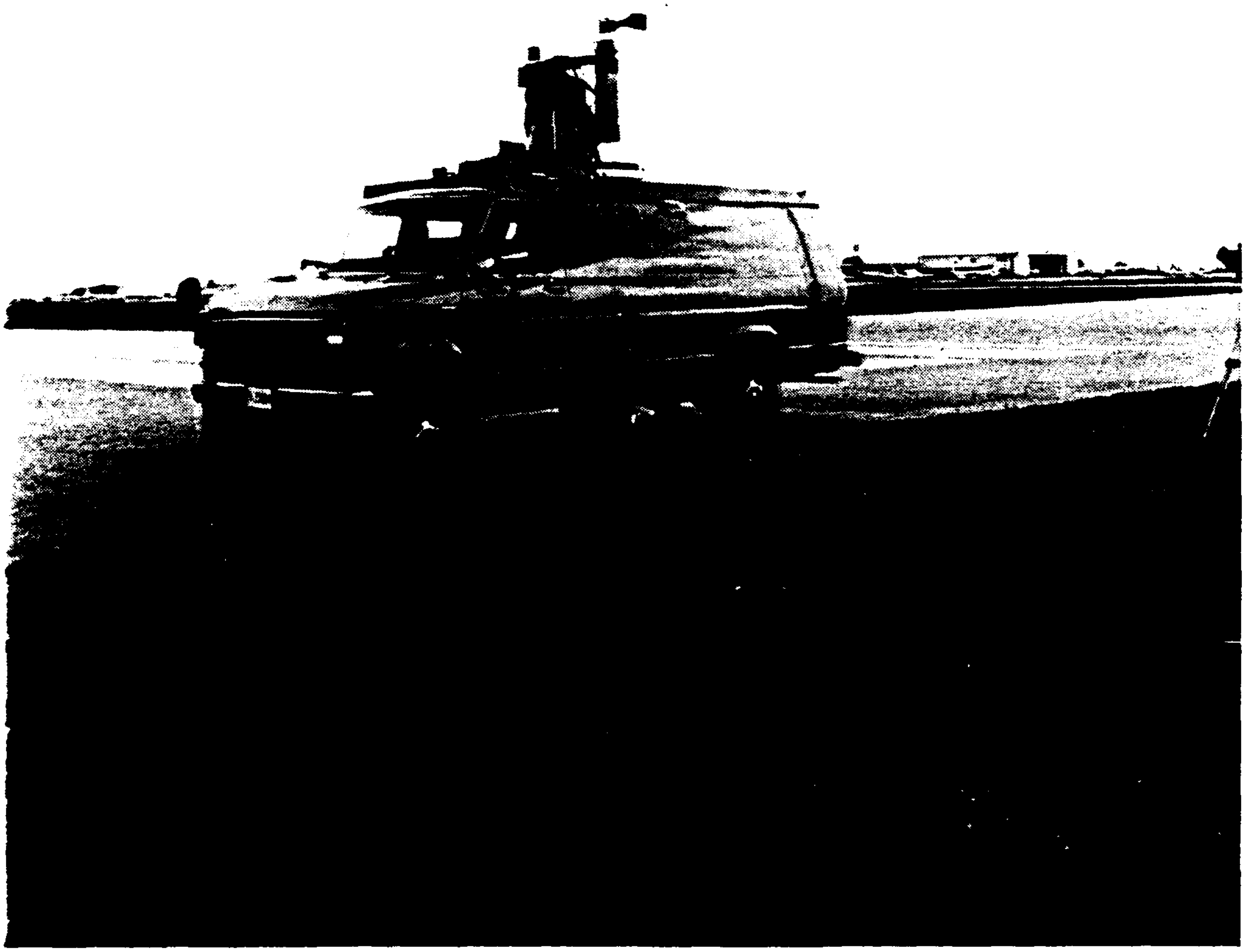


FIGURE 4. INSTRUMENTED TEST VAN

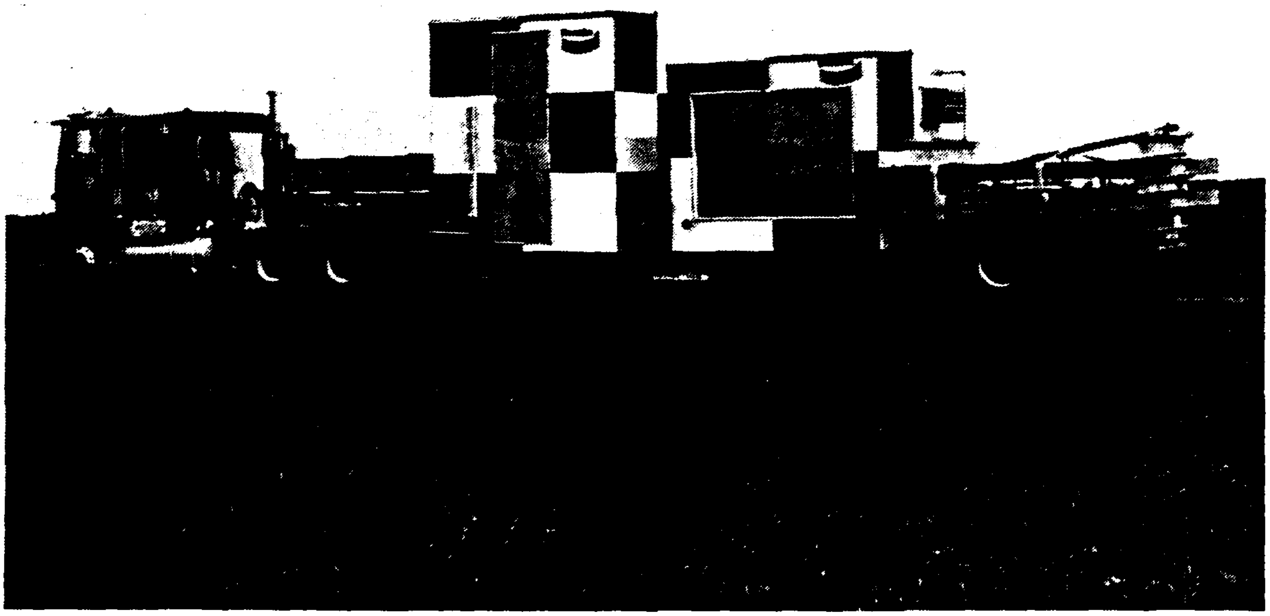


FIGURE 5. MLS EQUIPMENT LOADED ON TRUCK

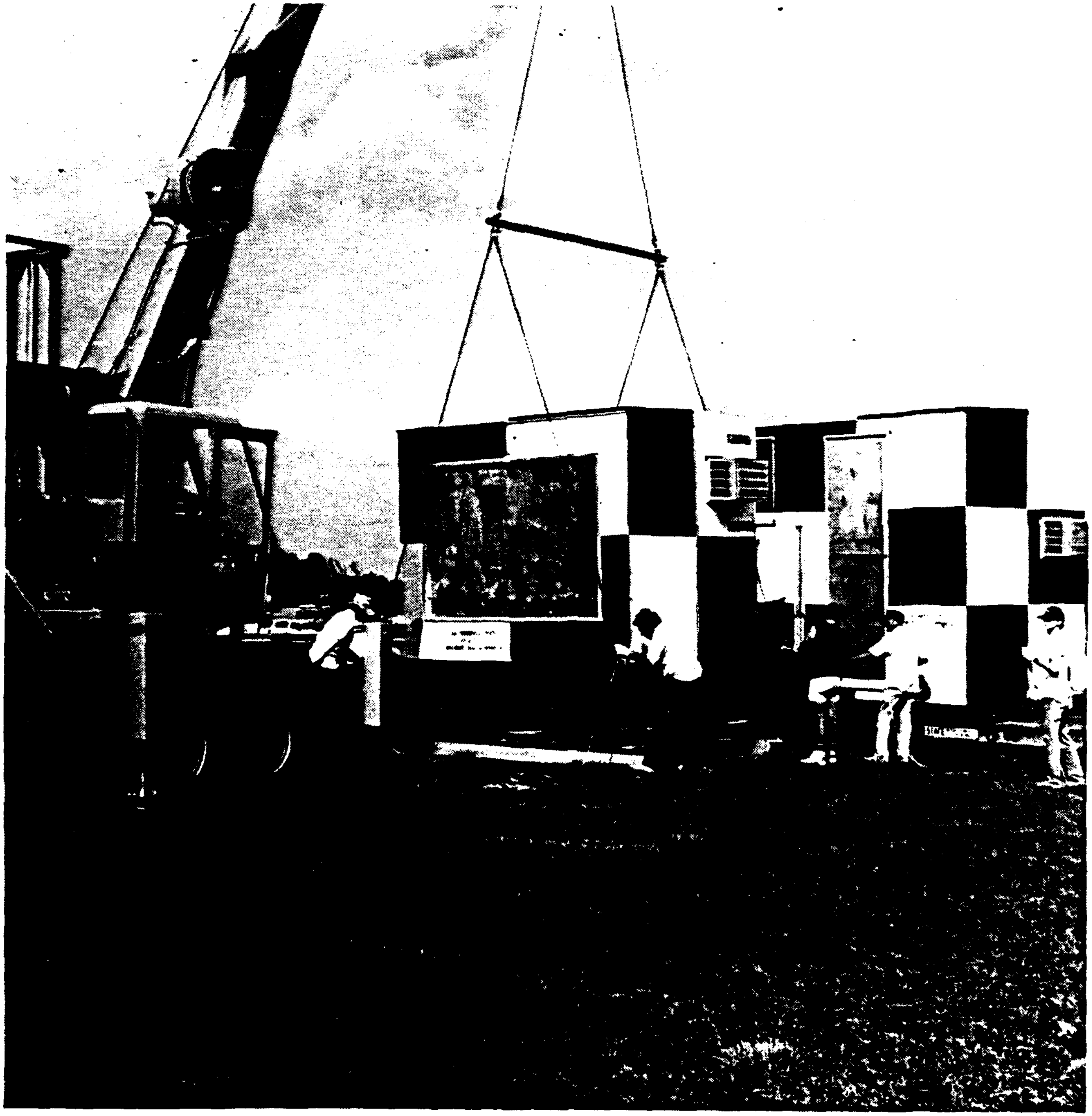


FIGURE 6. MLS AZIMUTH STATION BEING UNLOADED AND SET UP

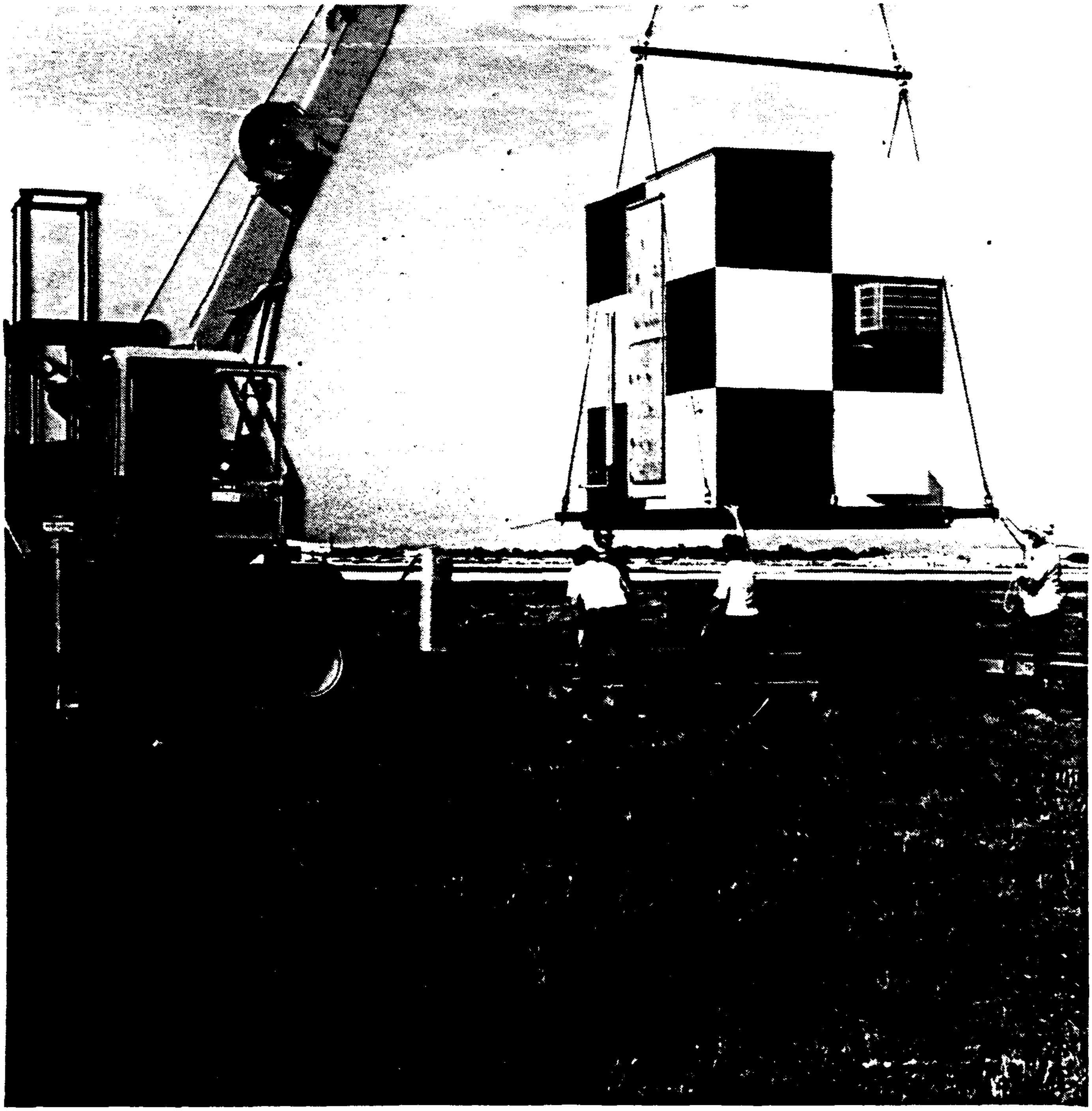
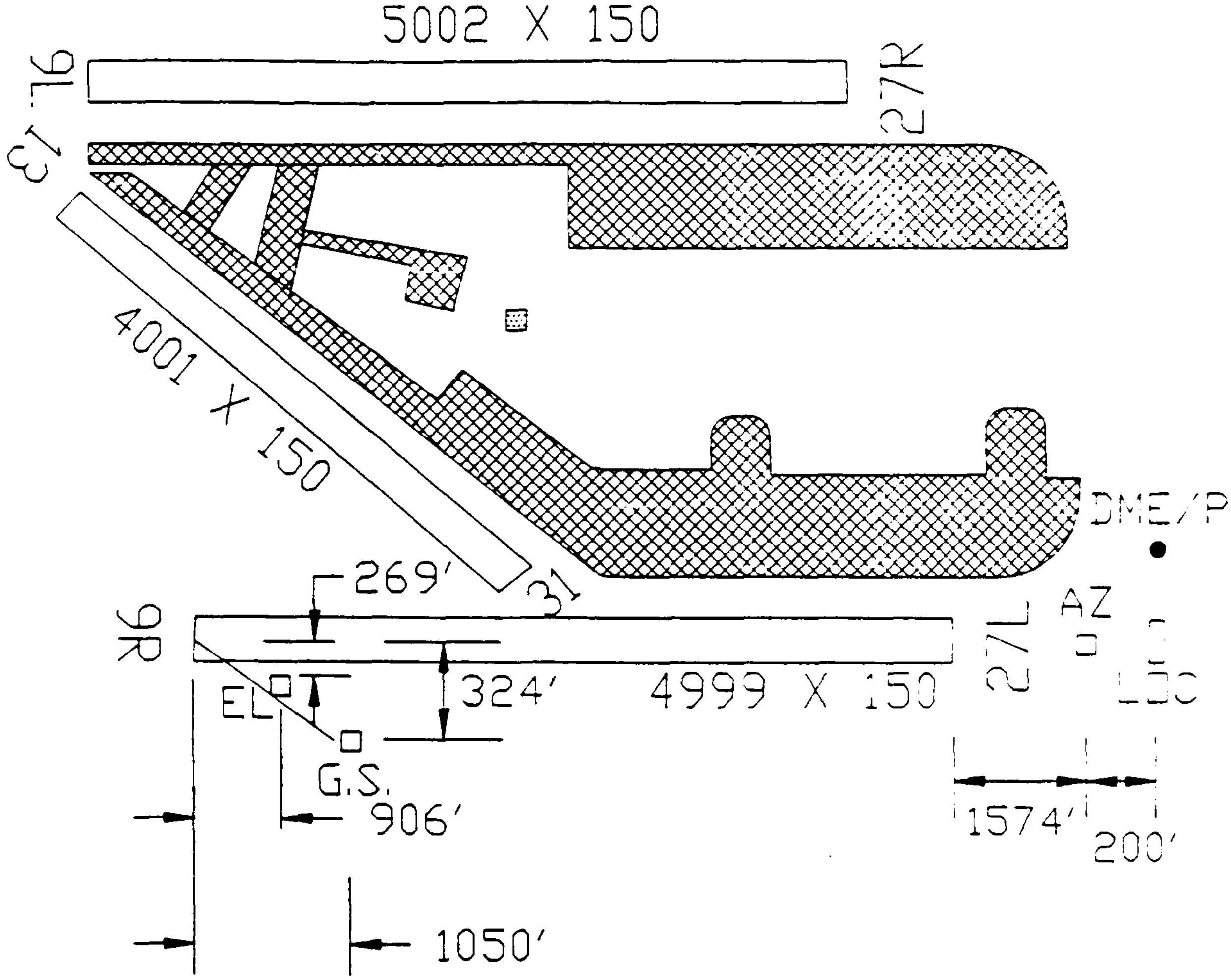


FIGURE 7. MLS ELEVATION STATION BEING UNLOADED AND SET UP



RUNWAY LAYOUT WITH ILS AND MLS LOCATION AT TAMIAMI AIRPORT

FIGURE 8. MIAMI/TAMIAMI SITING GEOMETRY

FIGURE 9. DME/P TRANSPONDER

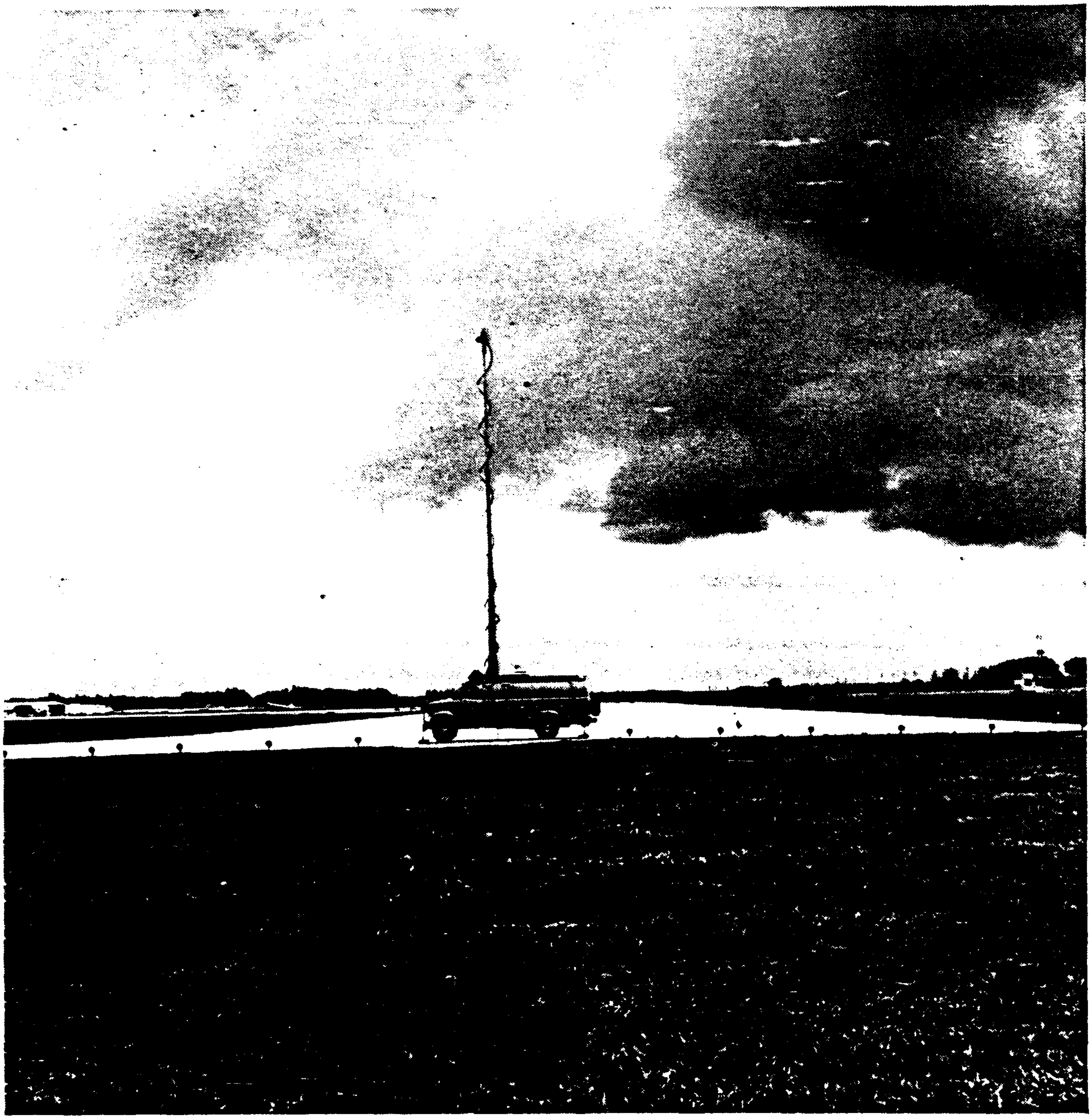


FIGURE 10. TEST VAN WITH EXTENDED MAST

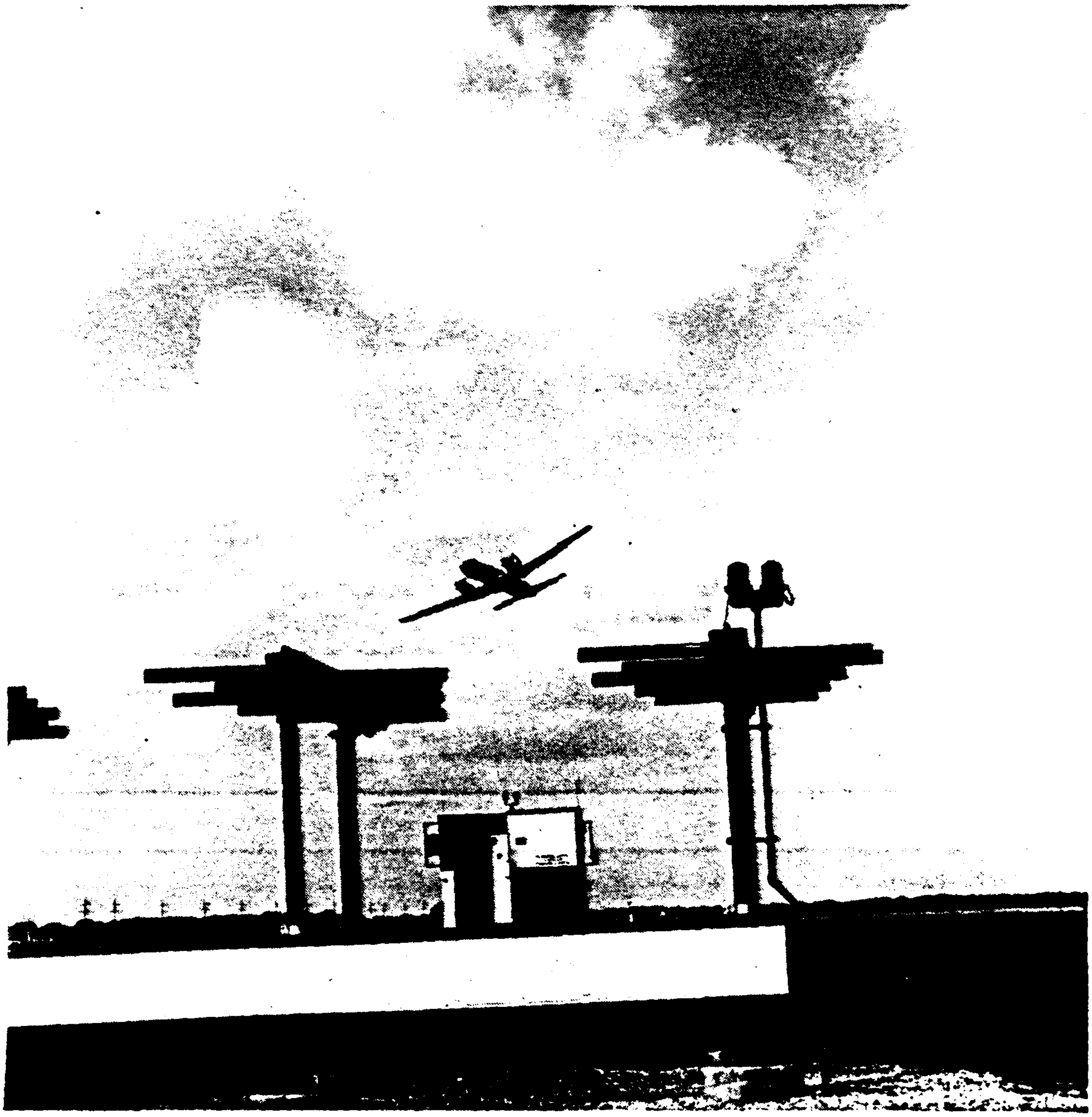


FIGURE 11. ILS LOCALIZER/MLS AZIMUTH COLLOCATION

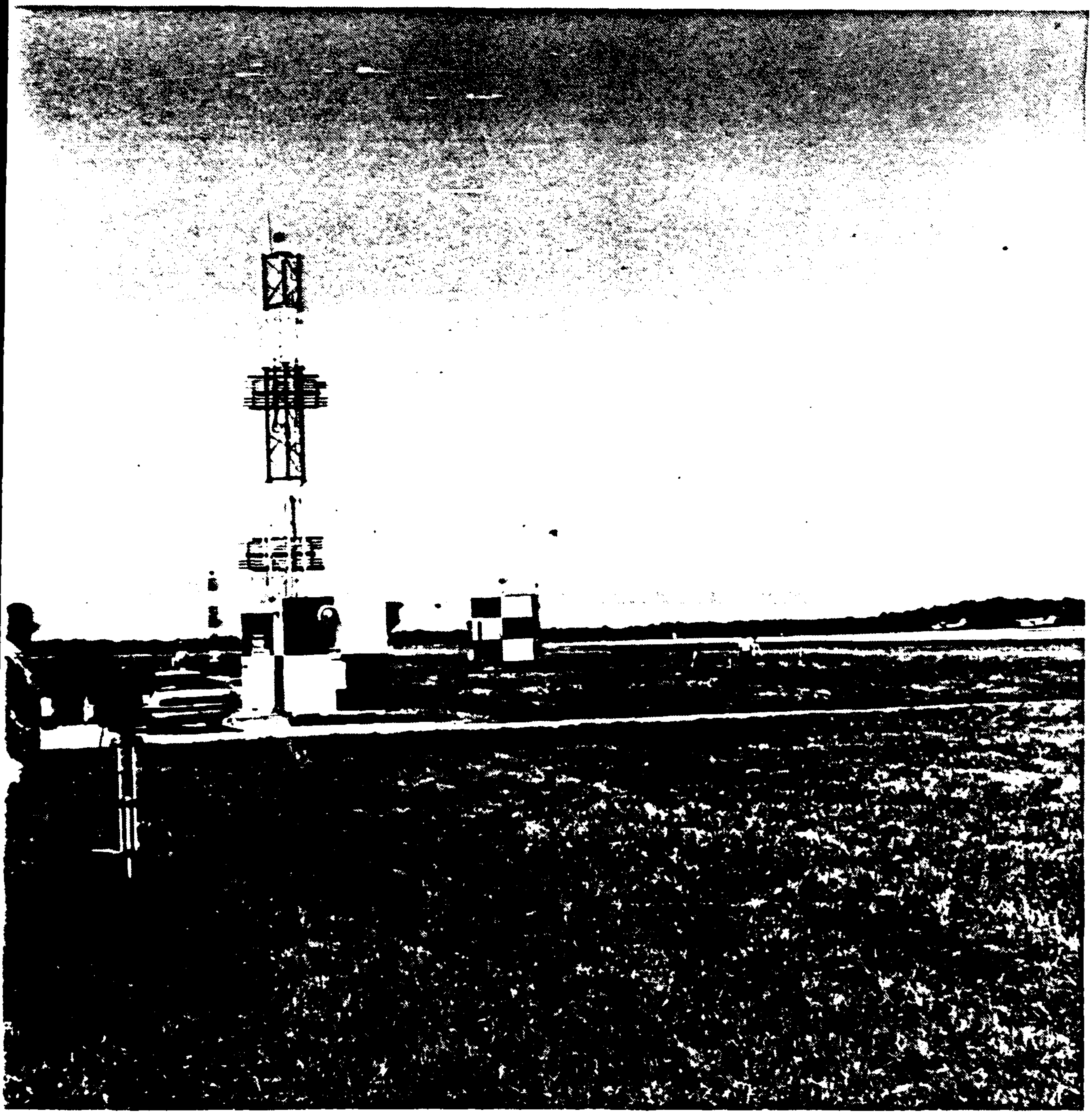


FIGURE 12. ILS GLIDE SLOPE/MLS ELEVATION COLLOCATION

FIGURE 13. FAA CONVAIR 580, N-91

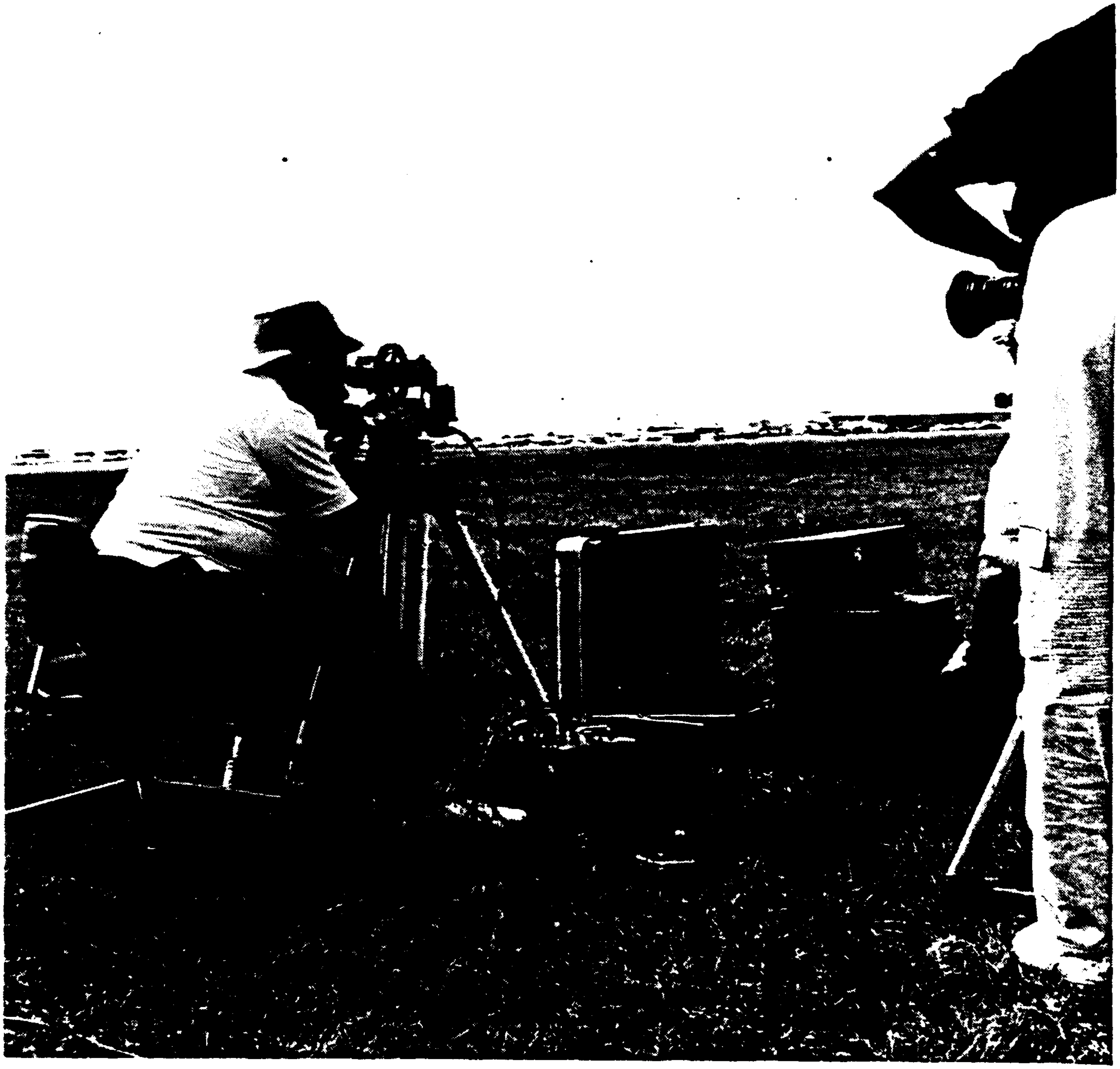


FIGURE 14. AIRCRAFT TRACKING USING AN RTT

FIGURE 15. MLS RNAV CONTROL DISPLAY UNIT IN COCKPIT

MLS RNAV CDU

```
3D        HH:MM:SS        DAT

AZ   __________           °
EL   __________           °
PDME __________           NMI
X    __________           FT
Y    __________           FT
Z    __________           FT
FR   __________     TO ______

DTW  __________           NMI
CTE  __________           FT
HTE  __________           FT
```

```
NAV STATE -       -> NONE
             3D   -> CASE 12
             2D   -> CASE 9B      As Taken From RTCA DO-198
                       OR
                     CASE 3
```

RECORDER STATE - DAT -> RECORDING

AZ - RAW ANGLE IN DEGREES
EL - RAW ANGLE IN DEGREES
PDME - RAW DME IN NMI

X,Y,Z - RELATIVE TO DATUM POINT(0,0,0)
ON R/W CL ACROSS FROM EL SITE

FR,TO - WAYPOINT NUMBERS

DTW - DISTANCE TO "TO WAYPOINT" IN NMI(3D), FT(2D)

CTE - CROSS TRACK ERROR IN FT

HTE - HEIGHT ERROR IN FT

FIGURE 16. CONTROL DISPLAY UNIT FORMAT AND LEGEND

MLS RNAV AND DATA COLLECTION SYSTEM

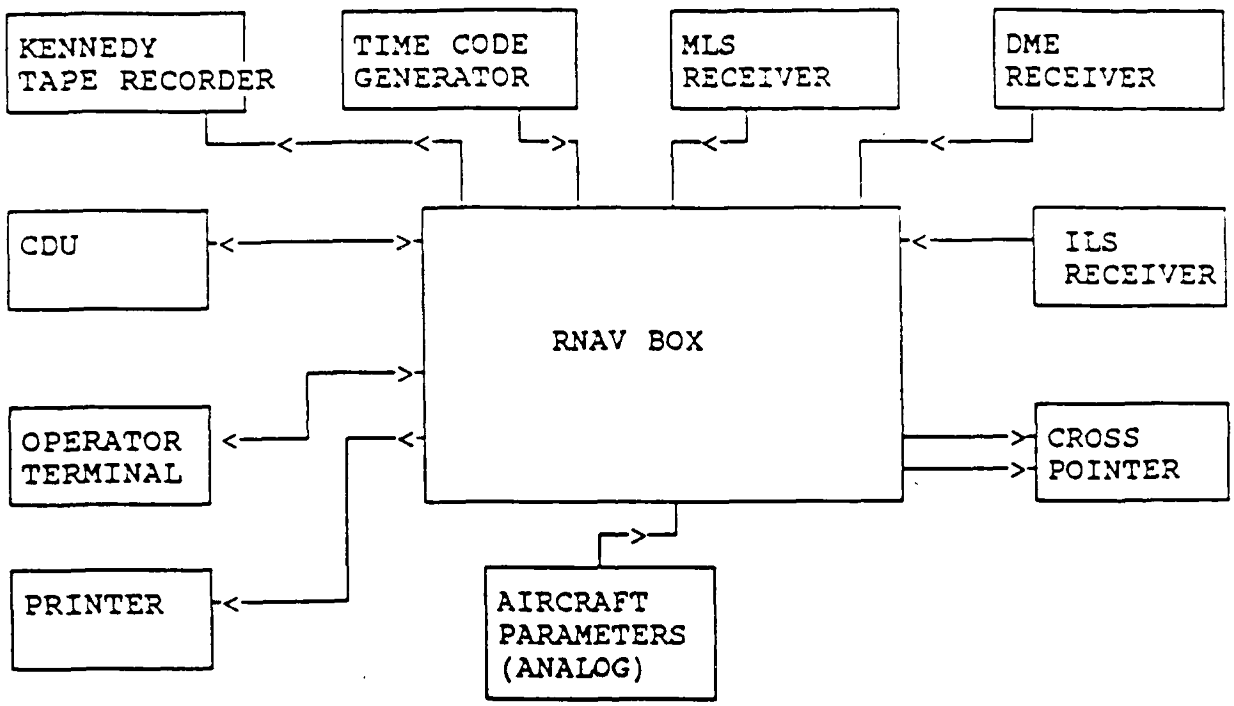


FIGURE 17. MLS RNAV AND DATA COLLECTION SYSTEM BLOCK DIAGRAM

FIGURE 18. SEMINAR PARTICIPANTS BOARDING DEMONSTRATION FLIGHT

FOR EXPERIMENTAL USE ONLY

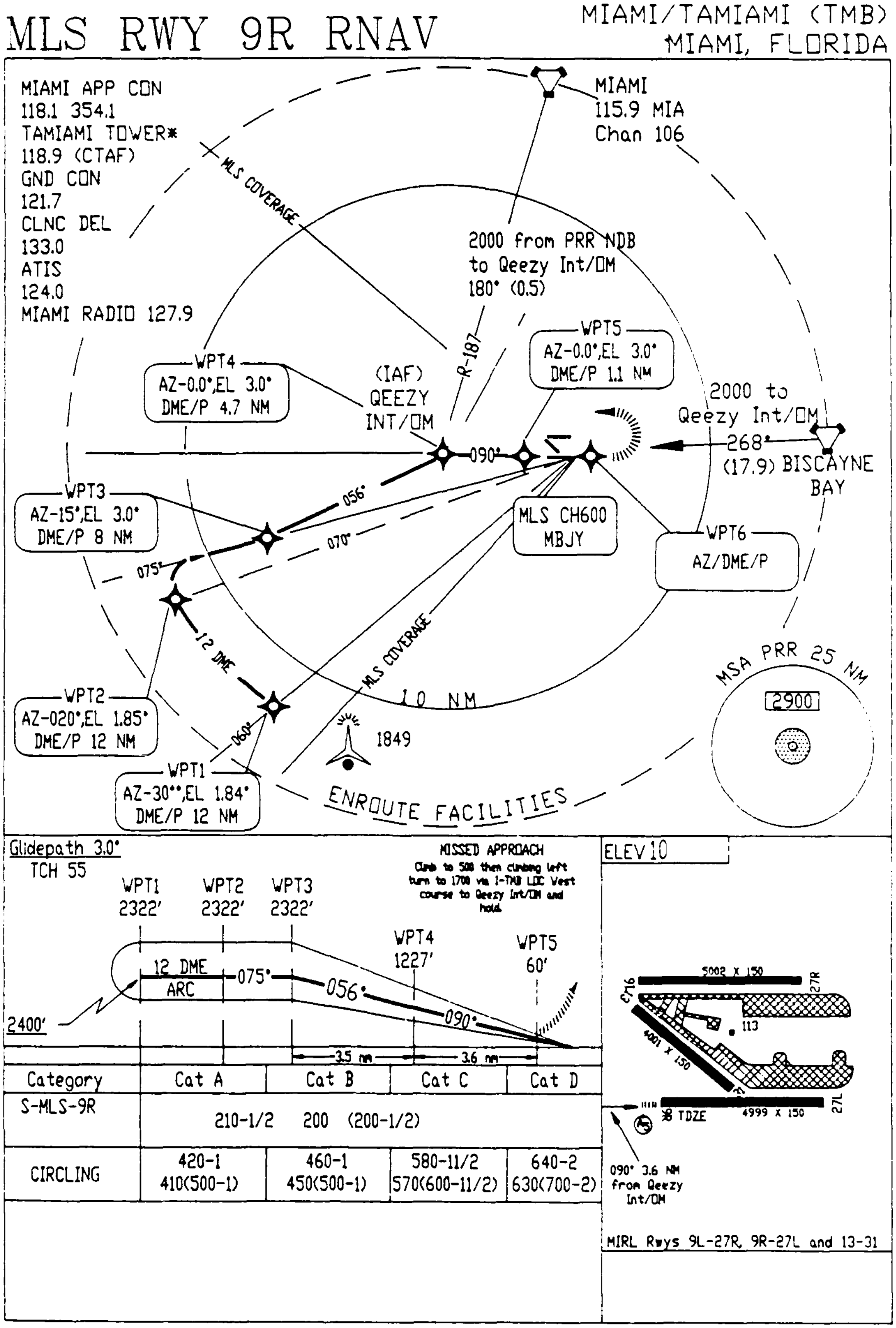
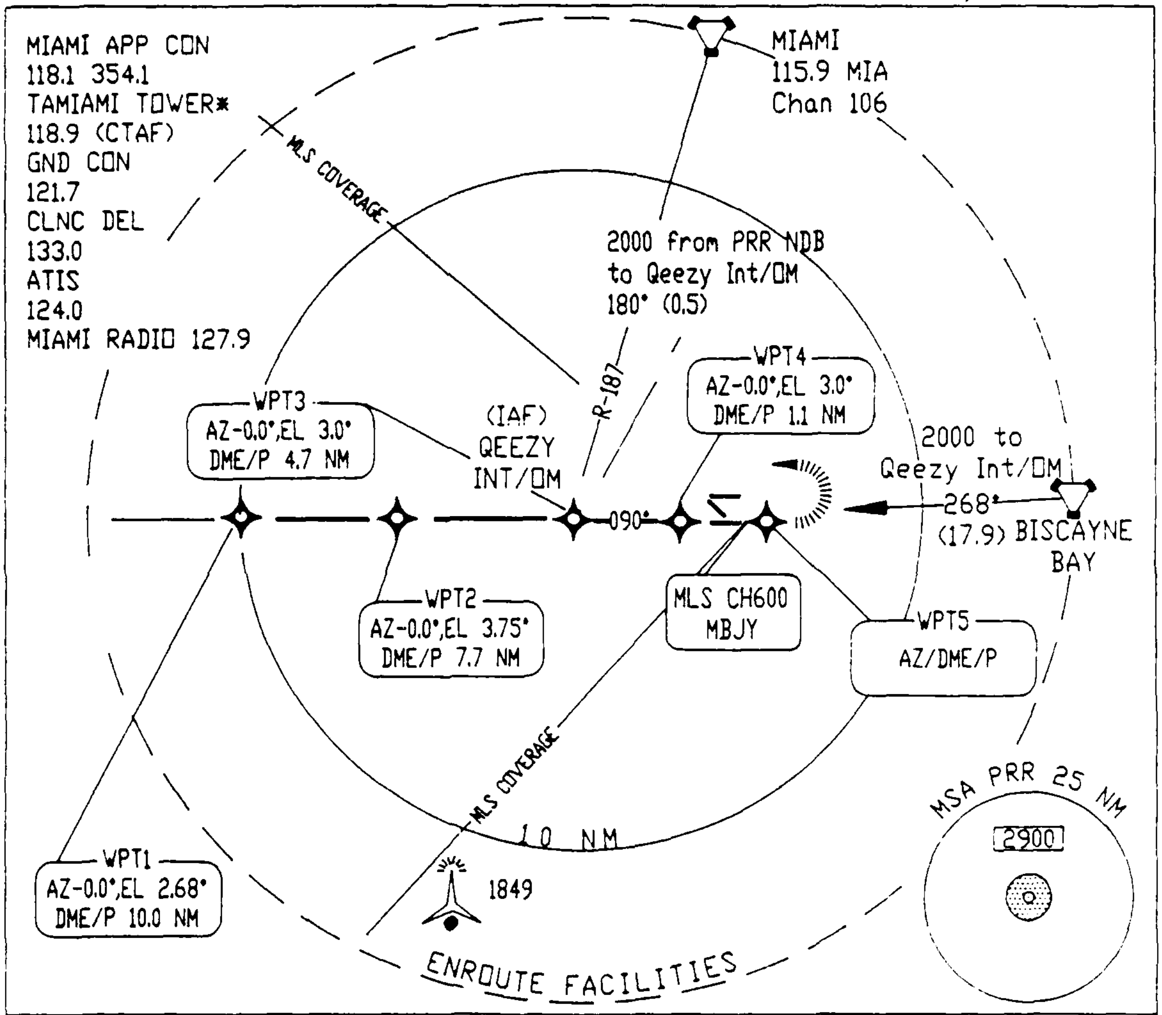


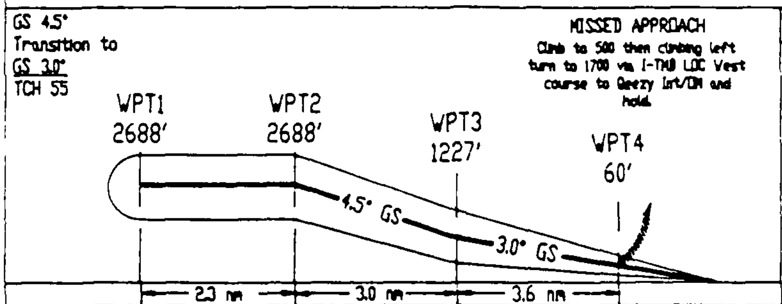
FIGURE 19. APPROACH PLATE, MLS RUNWAY 9R RNAV

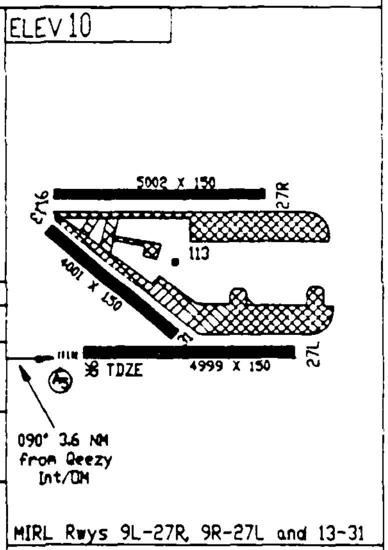
MLS RWY 9R RNAV

GLIDESLOPE TRANSITION 4.5° to 3.0°

MIAMI/TAMIAMI (TMB)
MIAMI, FLORIDA



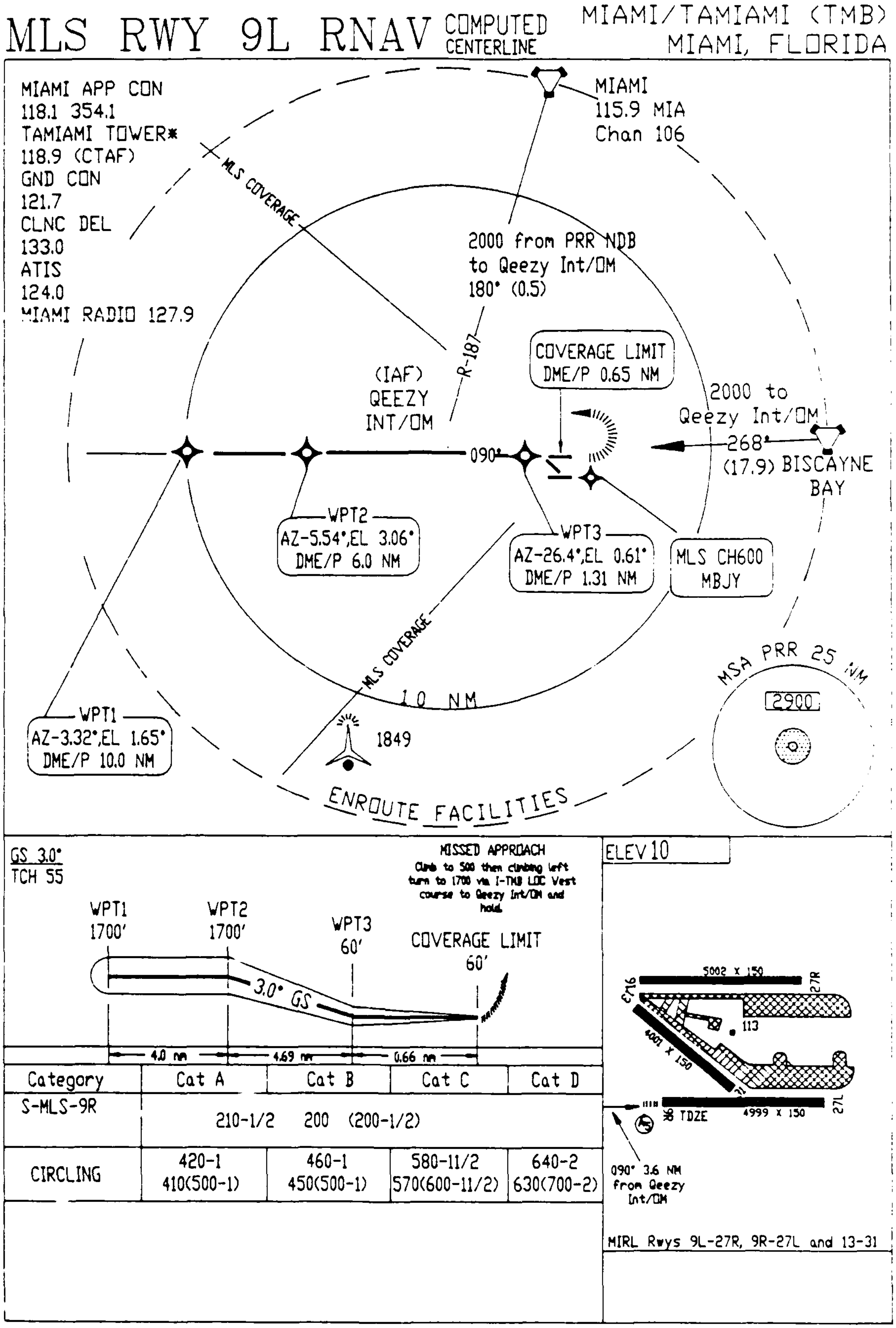




Category	Cat A	Cat B	Cat C	Cat D
S-MLS-9R	210-1/2 200 (200-1/2)			
CIRCLING	420-1 410(500-1)	460-1 450(500-1)	580-11/2 570(600-11/2)	640-2 630(700-2)

FLIGHT 20. APPROACH PLATE, MLS RUNWAY 9R RNAV, 4.5° TO 3° GLIDE SLOPE TRANSITION

FOR EXPERIMENTAL USE ONLY

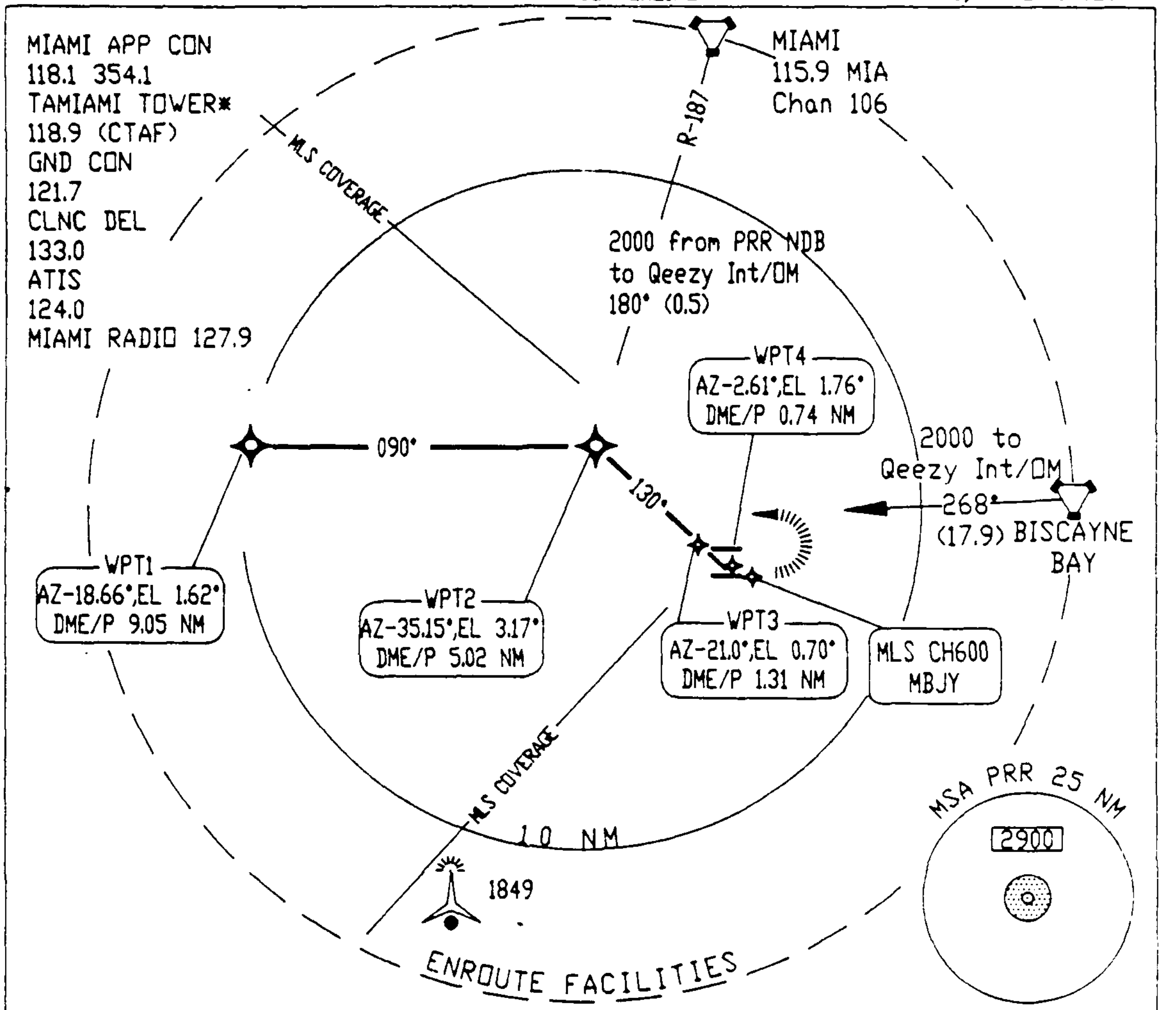


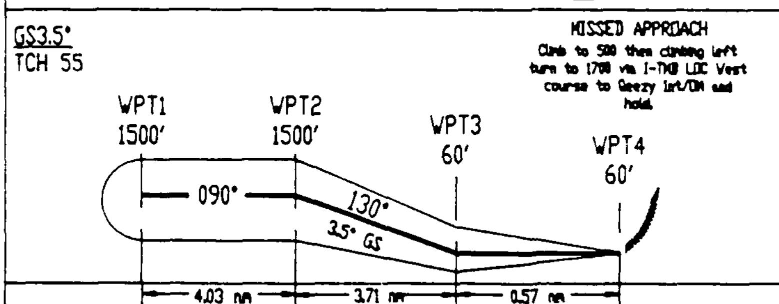
FLIGHT 21. APPROACH PLATE, MLS RUNWAY 13 RNAV

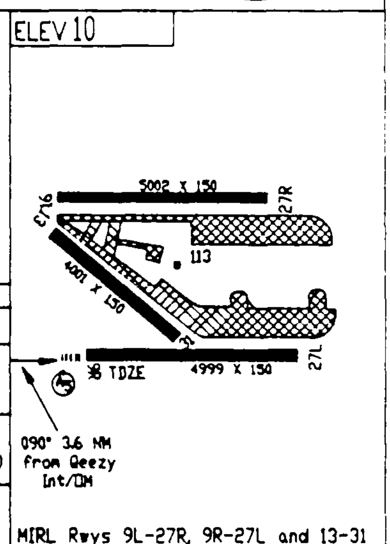
FOR EXPERIMENTAL USE ONLY

MLS RWY 13 RNAV COMPUTED CENTERLINE

MIAMI/TAMIAMI (TMB)
MIAMI, FLORIDA







Category	Cat A	Cat B	Cat C	Cat D
S-MLS-9R	210-1/2 200 (200-1/2)			
CIRCLING	420-1 410(500-1)	460-1 450(500-1)	580-11/2 570(600-11/2)	640-2 630(700-2)

FLIGHT 22. APPROACH PLATE, MLS RUNWAY 9L RNAV

FLIGHT 23. OHIO UNIVERSITY TRACKING TEAM